EXPERIMENT STATION.

KANSAS STATE

AGRICULTURAL COLLEGE.

Bulletin No. 46—May, 1894.

BOTANICAL DEPARTMENT.

RUSTS OF GRAIN, II.

MANHATTAN, KANSAS.
1894.

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EXPERIMENT STATION

OF THE

KANSAS STATE AGRICULTURAL COLLEGE,

MANHATTAN.

BULLETIN NO. 46—MAY, 1894.

BOTANICAL DEPARTMENT.

A. S. HITCHCOCK, M. Sc., Professor of Botany.
*M. A. CARLETON, M. Sc., Assistant in Botany.

SECOND REPORT ON RUSTS OF GRAIN.

In our first report on rusts, (Bulletin No. 38, March, 1893,) an account was given of the life history of the common grain rusts, and records of experiments on the prevention by means of spraying, and on the germination of the spores of red rust in various fungicides. Observations were also recorded concerning the wintering of the rust. In the present bulletin will be given additional observations on the wintering of the fungus, and also the details of further experiments with spraying in 1893.

Additional Observations on the Wintering of Puccinia Rubigo-vera.

In the first report, a number of observations were recorded on the germination of the uredo-spores of *Puccinia rubigo-vera*, gathered at various times through the winter. The opinion was expressed that the spores were not formed during the winter, but probably retained their vitality from the time of formation in the previous autumn; hence it was left unsettled as to whether the mycelium lived over winter and perpetuated the fungus, or whether the uredo-spores lived and germinated the following spring, thus

*Although Mr. Carleton resigned his position in February, his name is retained in this bulletin because of his responsibility for a large part of the work reported.

infecting the new crop. In order to test this point, a few plants, supposed to be infected, were transplanted to the greenhouse, on March 9. These showed on March 16 a number of bright red spots, the uredo-spores of *Puccinia rubigo-vera*. That these were not due to inoculation from adhering uredo-spores which had retained their vitality seems almost certain, from the fact that the period of incubation is about 13 days, while the spots appeared in this experiment in seven days; hence inoculation from the uredo-spores must have taken place before the plants were transplanted. But the conditions for inoculation at that time were very unfavorable. It seems most probable that the mycelium already present produced the spores, under the favorable conditions of temperature and moisture in the greenhouse.

On March 22, observations showed that the rust was spreading rapidly in the wheat fields along Wild Cat creek, and that it worked from the basal leaves upward.

The uredo-spores were gathered at various times during the spring, and were found to germinate readily in water and honey solution.

Some young plants of wheat were transplanted to the greenhouse in the fall. These were infected March 6 with uredo-spores taken from volunteer wheat transplanted to the greenhouse January 21.

In some cases the germinating spores from a water-drop culture were transferred to the leaves, which had been bedewed with an atomizer. In other cases the spores were applied without having been previously germinated.

On March 19, the rust pustules began to appear, and soon all the plants inoculated showed rust spots, including one plant which had been grown in the greenhouse from seed.

These experiments and observations, together with those recorded in the previous report, show that *Puccinia rubigo-vera* passes the winter in the tissues of the wheat plant in the mycelial condition, and also that the uredo-spores retain their vitality through the winter, and are capable of infecting their host the succeeding spring.

Observations upon Puccinia graminis.

This rust was quite abundant during 1893, and an effort was made to trace it through the winter. In order to aid in this work, a plat of ground was sown to wheat, oats, barley, and rye, and rusted oat plants transplanted in various parts to bring about infection. The oats became somewhat rusted by this means, but the wheat, although rusted, showed only *Puccinia rubigo-vera*.

Careful observations of these plats, and also of adjacent fields, were made during the autumn and early winter. The rust (*P. graminis*) became less and less abundant, and finally the most careful search failed to reveal its presence. It seems probable that *Puccinia graminis* does not

pass the winter in this vicinity in the uredo stage, nor in the mycelial condition. Whether or not it survives the winter further south is a question yet to be answered.

Inoculation Experiments.

A number of experiments were tried, to ascertain the relation of the rusts of wheat to those of some other cereals and grasses.

1. Wheat inoculated with uredo-spores of *Puccinia graminis* from wheat September 15. Successfully infected.

2. Wheat inoculated with uredo-spores of *P. graminis* from oats September 15. No infection.

3. Oats inoculated with uredo-spores of *P. graminis* from oats September 15. Successfully infected.

4. Oats inoculated with uredo-spores of *P. graminis* from wheat September 15. Infection successful, but slight.

5. Oats inoculated with uredo-spores of *P. graminis* from wheat September 22. No infection.

6. Rye inoculated with uredo-spores of *P. graminis* from wheat September 22. No infection.

7. Wheat inoculated with uredo-spores of *P. graminis* from wheat September 22. Successfully infected October 2.

8. Barley inoculated with uredo-spores of *P. graminis* from wheat September 22. One rust spot appears October 6.

9. Corn inoculated with uredo-spores of *P. graminis* from wheat September 22. No infection.

10. Oats inoculated with uredo-spores of *P. graminis* from oats September 22. Successfully infected October 2.

11. Rye inoculated with uredo-spores of *P. graminis* from oats September 22. No infection.

12. Barley inoculated with uredo-spores of *P. graminis* from oats September 22. No infection.

13. Wheat inoculated with uredo-spores of *P. graminis* from oats September 22. No infection.

14. Corn inoculated with uredo-spores of *P. graminis* from oats September 22. No infection.

15. Wheat inoculated with uredo-spores of *P. sorghi* from corn September 22. No infection.

16. Oats inoculated with uredo-spores of *P. sorghi* from corn September 22. No infection.

17. Corn inoculated with uredo-spores of *P. sorghi* from corn September 22. Rust spots appeared September 27; hence may have been infected at beginning of experiment.

18. Wheat inoculated with uredo-spores of *P. rubigo-vera* from wheat December 29. Rust spots appeared January 16, and probably sooner.

19. Oats inoculated with uredo-spores of *P. rubigo-vera* from wheat December 29. No infection.

20. Wheat inoculated with uredo spores of *P. rubigo-vera* from blue grass (*Poa pratensis*) December 29. No infection.

21. Oats inoculated with uredo-spores of *P. rubigo-vera* from blue grass December 29. No infection.

22. Oats inoculated with uredo spores of *P. graminis* from oats December 29. Rust spots appeared January 16, and probably sooner.

In October, plants of oats, wheat, rye and orchard grass (*Dactylis glomerata*) were inoculated with uredo-spores of *P. graminis* from oats. Of these, only the oats were infected.

At the same time, another series of the same kinds of plants were inoculated with uredo-spores of *P. rubigo-vera* from wheat. Only the wheat plants were infected.

Wheat inoculated with uredo-spores from blue grass produced no effect.

In all cases where infection resulted, the period of incubation was about 13 days.

These experiments seem to show that the rusts of various cereals are probably physiological species. If so, there is little danger of infection from one kind of grain to another.

SPRAYING EXPERIMENTS.

In these experiments, no attempt was made to ascertain the best methods of preparing and applying the fungicides, nor to determine the cost of such operations. The object being, rather, to determine what chemicals would prevent rust when applied in solutions of such strength as to avoid injury to the plants sprayed.

Experiments showing the effects of various solutions upon the germination of uredo-spores of the three cereal rusts, *Puccinia graminis* Pers., *Puccinia rubigo-vera* (D.C.) Wint., and *Puccinia coronata* Corda, which were reported in Bulletin No. 38 from this Station, suggested certain compounds as being of probable value as fungicides. They are as follows, given in the order of greatest probable effectiveness: Potassium bichromate, mercuric chloride, copper sulphate, copper acetate, copper nitrate, lead acetate, copper chloride, ferric chloride, zinc chloride, and ferrous sulphate. It was decided to try field experiments in spraying wheat with these 10 solutions, and compare the results with those obtained in the laboratory. Most of the solutions prevented germination in the laboratory experiments with a strength of 1 part in 1,000. It was thought, therefore, that a strength of 1 part in 100 would be sufficient with which to begin the field experiments. To these fungicides were afterwards added common salt and boric acid, the former suggested from the supposed effects of ocean spray upon rusted wheat grown near the seashore, and the latter from the fact of its having been recently suggested by various parties as a fungicide of probable value.

The experiments as originally planned could not be carried out. In the fall of 1892, twelve different varieties of wheat, chosen to represent as great variation as possible in time of maturity, rust-resistant power, etc., had been drilled in for use in these experiments. Each variety was to be treated with each of the twelve fungicides, in plots 10 feet long and the width of the two-horse drill, and corresponding duplicate plots, alternating with these, were to be left untreated, making 288 plots in all. But the wheat, being on dry upland with northern exposure, was almost wholly killed by the combined effects of prolonged autumn drought followed by severe freezes.

Finally, the farm department kindly allowed us to measure off for our use plots equal in size to those mentioned above, from each of a series of much longer plots planted for variety tests of wheat. In using these plots for our experiments, we could not expect to obtain as satisfactory results as with those to be used in the original plan if the wheat had not been kille The new plots had the special disadvantage of including a considerable vari tion in soil, so that the growth of the wheat, even in the same plot and the same variety, was not always uniform.

The results of the spraying upon wheat are given in the following table Spraying was not begun until about three days after the rust began to ap pear in any considerable quantity. The numbers given are those assigne to the large plots by the farm department. A report on the varieties co responding to these numbers is given in Bulletin No. 40 of this Static (pp. 60, 61). In every case, all that portion of the long plot not used b us in spraying was allowed to serve as a check. The letters A, B, C, et refer to additional plots of same size (10 feet long and width of the drill measured from average portions of a continuous tract of Currell wheat. I the column "Strength" are given the number of parts (by weight) of rai water in which one part of the compound was dissolved. *Puccinia rubig vera* was the predominant rust at first, but finally *Puccinia graminis* becan quite abundant, particularly on the stems:

JUNE 16, 1893.

No.	Variety.	Fungicide.	Strength.	Remarks.
25	Diehl-Mediterannean	Ferrous sulphate	1:50	Effective, but injured wheat also.
28	Buckeye	Potassium bichromate	1:100	Killed the wheat; solution too stron
34	Gold Medal	Boric acid	1:100	No satisfactory results.
38	Valley	Ferrous sulphate	1:50	Effective, but injured wheat badly
41	White Track	Mercuric chloride	1:1000	No satisfactory results.
42	Lehigh	Boric acid	1:100	No results.
44	White Blue Stem	Copper sulphate	1:100	Effective, but injured wheat.
47	German Emperor	Salt	1:50	No results.

JUNE 17, 1893.

No.	Variety.	Fungicide.	Strength.	Remarks.
1	Bullard's Velvet Chaff	Salt	1:50	No results.
2	Zimmerman	Mercuric chloride	1:500	No results; very little rust present originally.
3	Yellow Alabama	Lead acetate	1:100	No results.
7	Extra Early Oakley	Copper sulphate	1:200	No satisfactory results, but seemed slightly affected.
8	Fultz	Salt	1:100	No results.
12	Red May	Boric acid	1:100	No results.
13	Farquhar	Copper sulphate	1:200	Somewhat effective; wheat injured
16	Canadian Wonder	Salt	1:100	No results.
17	Tasmanian Red	Ferric chloride	1:100	Effective, but wheat also killed.
18	Theiss	Zinc chloride	1:100	Effective, but injured wheat also.
19	Bearded Monarch	Mercuric chloride Potassium bichromate	1:1000 1:100	No satisfactory results.
22	Early May	Copper acetate	1:100	No results; not much rust originally
23	Deitz	Mercuric chloride Potassium bichromate	1:1000 1:100	No satisfactory results.
24	Velvet Chaff	Copper nitrate	1:100	Killed the wheat; solution too strong
27	Lancaster	Copper sulphate	1:100	Killed the wheat to some extent.
30	Davis	Lead acetate	1:100	No results.
32	Boyer	Ferric chloride	1:100	Effective; injured wheat badly.
33	Dallas	Copper nitrate	1:100	Killed the wheat.
36	Red Fultz	Zinc chloride	1:100	Effective, but injured wheat.
37	Fulcaster	Salt	1:50	No results.
39	Seneca Chief	Mercuric chloride	1:500	No results.
40	Turkey	Copper sulphate	1:100	Wheat injured.
A.	Currell	Boric acid	1:100	No results.
B.	Currell	Potassium bichromate	1:500	No satisfactory results.
C.	Currell	Potassium bichromate	1:500	No satisfactory results.
D.	Currell	Mercuric chloride	1:200	Effective; wheat injured some.
E.	Currell	Mercuric chloride	1:200	Effective; wheat injured some.
F.	Currell	Boric acid	1:100	No results.

JUNE 19.

No.	Variety.	Fungicide.	Strength.	Remarks.
21	California Blue Stem	Copper chloride	1:100	Effective, but wheat injured some.
43	Oregon Club	Copper chloride	1:100	Effective, but wheat injured some.

The rust appeared quite suddenly on the above plots, and also ran its course very quickly, giving time for only one spraying.

In the meantime, *Puccinia graminis* was beginning to show on the experimental oats of the farm department, and finally became so abundant that by harvest time the crop was very materially injured. Indeed, this season, the oat crop in large portions of the state was much injured by this

rust. In Wabaunsee county, some fields were almost wholly destroyed, and the straw so badly lodged that it could scarcely be harvested.

It may be of interest to state here, that while *Puccinia coronata* was the predominant species on oats in 1892, with very little *Puccinia graminis*, in 1893 many diligent searches failed to discover a single specimen of the former on *any* host, in the vicinity of Manhattan, while the latter was very abundant, and, on oats, to the entire exclusion of both the other species.

The farm department again furnishing the plots, it was decided to repeat the spraying experiment on the oats. The results are given in the next series of tables. Again the spraying was begun two or three days after the rust began to appear in quantity. The plots were twice the length of the preceding, but of the same width, and were measured off from a continuous tract of a variety of white oats of fairly uniform growth. The remainder of the tract was allowed to serve as check for all plots, as in case of the Currell wheat plots of the preceding experiments. Three of the compounds used in the preceding experiments, copper chloride, copper acetate, and zinc chloride, were omitted in these.

JUNE 20, 1893.

No. of plot.	*Fungicide.*	*Strength.*	*Remarks.*
1	Copper sulphate	1:200	Quite effective; oats slightly injured.
2	Copper nitrate	1:200	Quite effective; oats considerably injured.
3	Ferrous sulphate	1:100	Somewhat effective; leaves injured.
4	Mercuric chloride	1:500	Rather effective; oats not injured.
5	Salt	1:100	No results.
6	Lead acetate	1:100	No appreciable results.
7	Boric acid	1:100	No results.
			JUNE 21.
8	Potassium bichromate	1:200	Somewhat effective; plants not injured.
9	Ferric chloride	1:200	Effective; plants injured.
			JUNE 24.
1	Copper sulphate	1:300	Disease very materially checked; plants slightly injured.
2	Copper nitrate	1:300	Disease very much checked; plants still injured somewhat.
3	Ferrous sulphate	1:300	Only slightly effective; leaves injured.
4	Mercuric chloride	1:400	Disease very much checked; plants injured slightly.
5	Salt	1:100	No results.
6	Lead acetate	1:100	No satisfactory results.
7	Boric acid	1:100	No satisfactory results.
8	Potassium bichromate	1:100	Disease almost wholly checked; plants considerably injured.
9	Ferric chloride	1:300	About the same in effect as the last.

JUNE 29, 1893.

No. of plot.	Fungicide.	Strength.	Remarks.
5	Salt	1:60	No results.
7	Boric acid	1:80	Slightly effective.

Further spraying on this day was prevented by rain.

JULY 1.

8	Ferrous sulphate	1:100	Somewhat effective; leaves much injured.
5	Salt	1:60	No results, except, perhaps, a slight injury to the plant.
6	Lead acetate	1:80	Slightly effective.
7	Boric acid	1:80	Slightly effective.

It was intended to spray every five days, but rains interfered somewhat. It will be noted that most of the solutions after the first spraying were made more dilute, although some were afterward made stronger again. Some of the solutions were still perhaps stronger than necessary for killing the disease, and certainly too strong for the welfare of the plants. The two chief requisites necessary for successfully spraying cereals for rust seem now to be (1) to obtain a solution of sufficient strength to effectually combat the rust without injury to the plant, and (2) to find some method of covering the plants more completely with the spray. The latter purpose would not be wholly accomplished, even with an extremely fine spray, since many of the leaves have a provoking tendency to turn their under surfaces upward, thus preventing the opposite surface, which is usually the source of infection by the rust, from being sprayed. However, the former requisite, taking as a basis for a conclusion, not only our own experiments here, but those of various others, seems to be practically within our reach.*

On June 28, specimens of the plants were taken from the treated plots, and compared, as to the amount of rust, with specimens from the untreated portion. Taking the average amount of rust on the untreated portion as 100 per cent., the amounts on the plots treated with the different fungicides were about as follows, approximately: Salt, 100 per cent.; boric acid, 85 per cent.; ferrous sulphate, 85 per cent.; lead acetate, 85 per cent.; copper sulphate, 50 per cent.; copper nitrate, 25 per cent.; mercuric chloride, 25 per cent., potassium bichromate, 10 per cent.; ferric chloride, 10 per cent.

* For an account of an extensive series of experiments carried on by the United States department of agriculture, see Journal of Mycology, VII, 3, pp. 195–226.

I. In the vicinity of Manhattan, the common wheat rust, *Puccinia rubigo vera,* passes the winter in the tissues of the wheat plant in the mycelial condition. During the warm weather of spring, a crop of spores is pro- duced which, under favorable conditions, may rapidly spread the disease The infection of the winter wheat in the fall is materially aided by volun- teer wheat, which carries the rust through the few months following harvest The red rust spores are capable of maintaining their power of germinatio *through the winter, and thus infecting the crop the following spring.*

II. There is no evidence to show that the second kind of wheat rus (*Puccinia graminis*) survives the winter here, either in the mycelial condi- tion or in the uredo stage, though it may do so further south.

III. A series of inoculation experiments shows that both wheat and oat are easily infected by rust from the same kind of grain, but not by the sam kind of rust from other grains; *e.g.*, wheat is infected by rust from wheat but not by rust from oats, corn, or blue grass. Hence there is little dange of infection from one kind of grain to another.

IV. The spraying experiments show that certain fungicides, as potassiu bichromate and ferric chloride, are effective in preventing rust, but that with our present knowledge concerning methods of spraying, it seems im possible to sufficiently cover the foliage. For this reason, although the rus can be largely decreased, we cannot attain prevention, as is done in suc diseases as the grape mildew. Furthermore, it is extremely doubtful i spraying of wheat or oats would pay, even if effective.

A more promising plan is the breeding of varieties of grain which shal be rust resisting, the so-called "rust-proof" varieties.

NOTICE.

The bulletins of 1894 will include full reports of all completed experiments, and will be reprinted with the annual report of the Station. They will be paged consecutively, inning with No. 46, and a complete index will be furnished at the close of the year, nable all who preserve them to bind in a single volume.

The bulletins and annual reports of this Station will be sent free to residents of Kan-, on application to the Secretary of the Experiment Station, Manhattan, Kas.

Published by order of the Council. I. D. GRAHAM, *Secretary.*

PREVIOUS PUBLICATIONS.

BULLETINS.

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No. 34, September, 1892, "Experiments in Feeding Steers."

[1] Out of print. The annual reports for 1888 and 1889 contain the subject-matter of Bulletins No inclusive.

*No. 35, December, 1892, "Actinomycosis Bovis, or 'Lumpy Jaw' of Cattle." "Some Observatio[illegible] upon Loco."

No. 36, December, 1892, "Experiments with Sorghum and with Sugar Beets."

No. 37, December, 1892, "Experiments in Potato Culture."

No. 38, March, 1893, "Preliminary Report on Rusts of Grain."

No. 39, August, 1893, "Experiments in Feeding Steers.—II."

No. 40, August, 1893, "Experiments in Wheat."

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No. 42, December, 1893, "Experiments with Oats."

No. 43, December, 1893, "Experiments with Sorghum and Sugar Beets."

No. 44, December, 1893, "Further Study of Native Grapes."

No. 45, December, 1893, "Experiments with Corn."

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Summary of Bulletins 38 to 45, outline of other work, meteorological summary for 36 years, wi[illegible] index to both bulletins and report.

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